
Test Procedure for

DETERMINING THE COEFFICIENT OF THERMAL EXPANSION OF CONCRETE



TxDOT Designation: Tex-428-A

Effective Date: June 2011

1. SCOPE

- 1.1 Use this method to determine the linear coefficient of thermal expansion (CTE) of concrete by measuring the change in length of concrete cores or cylinders subjected to a range of temperatures.
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2. APPARATUS

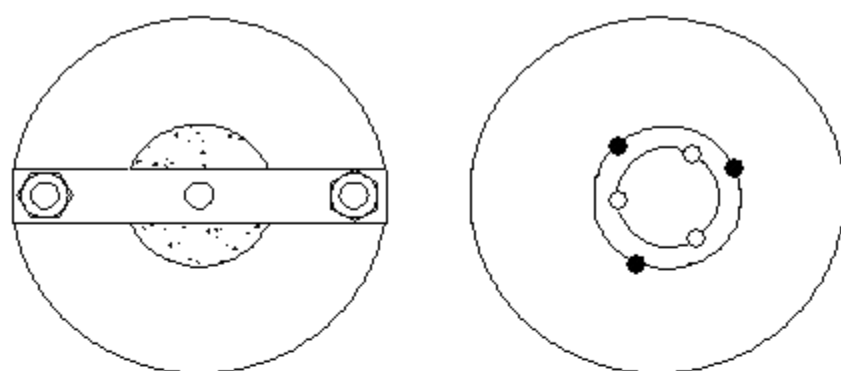
- 2.1 *Water bath*, capable of maintaining temperatures of $50 \pm 1^\circ\text{C}$ ($122 \pm 2^\circ\text{F}$) and $10 \pm 1^\circ\text{C}$ ($50 \pm 2^\circ\text{F}$) with the deionized water level maintained at least 1 in. (25.4 mm) above support frame.
- 2.2 *RTD*, accurate to 0.12°C (0.22°F) and with a minimum resolution of 0.01°C (0.02°F), in appropriate location to measure water bath temperature, approximately within 1 in. of the test specimen.
- 2.3 *Scale or balance*, Class G2 in accordance with Tex-901-K, with a capacity of approximately 44 lb. (20 kg).
- 2.4 *Caliper, comparator, or other suitable device*, to measure the specimen length to the nearest 0.005 in. (0.1 mm).
- 2.5 *Support frame*, as shown in Figure 1.
- 2.5.1 The frame should be made of non-corroding material to minimize the effects of submersion in a water bath. Vertical members should be made of Invar, a low thermally expansive material. All other components should be made of 304 stainless steel.
- 2.5.2 The threaded LVDT measurement tip should have a threadlocker (e.g., Loctite 242) applied to prevent loosening during a test. The frame may be adjustable to accommodate different sample lengths; however, calibrations will be required after each adjustment.
- 2.5.3 The base plate should be 10 in. in diameter or rectangular 10 in. \times 5 in.
- 2.5.4 The base plate should have three semi-spherical support buttons equally spaced to form 2-in. and 3-in. diameter circles.
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- 2.6 *Concrete saw, capable of sawing the ends of a cylindrical specimen perpendicular to the axis and parallel to each other.*

- 2.7 *Submersible LVDT gage head with excitation source and digital readout, with a minimum resolution of 0.00001 in. (0.00025 mm) and a range suitable for the test. For ease in setting up the apparatus, a range of ± 0.1 in. (± 3 mm) is practical.*

- 2.8 *Reference bar, made of 304 stainless steel or other non-corrosive material of known thermal expansion, 7 in. \pm 0.001 in. (178 mm \pm 0.025 mm) in length and approximately 4 in. (102 mm) in diameter.*

- 2.9 *Calibration block, size 0.10005 in. individual gauge block.*



TOP VIEW

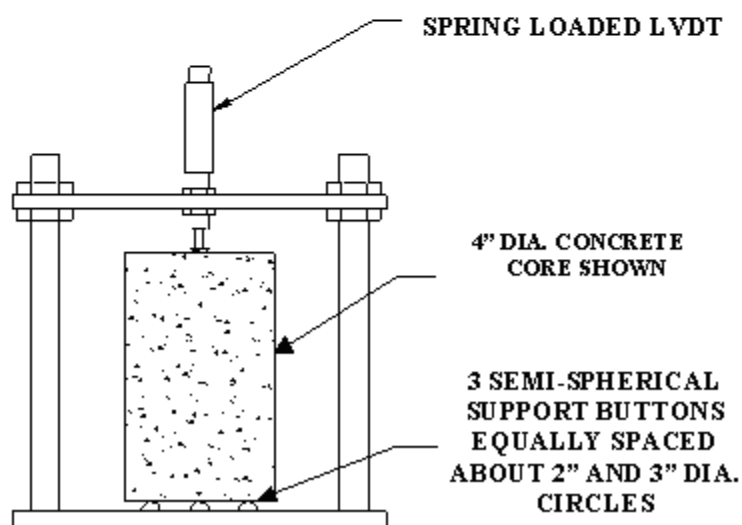


Figure 1—Support Frame

PART I—DETERMINING THE COEFFICIENT OF THERMAL EXPANSION

3. TEST SPECIMENS

- 3.1 Test specimens should consist of 4 in. (100 mm) or 6 in. (150 mm) nominal diameter cores or cylinders. A minimum of two test specimens are required.
- 3.1.1 Obtain cores in accordance with Tex-424-A.
- 3.1.2 Cast cylinders in accordance with Tex-447-A.
- 3.2 Saw the specimen perpendicular to the axis, at a standard length of 7 ± 0.1 in. (178 ± 2 mm). Neither end of the test specimen should depart from perpendicularity to the axis by more than 0.5° [approximately equivalent to 0.12 in. per 12 in. (1 mm per 100 mm)]. Saw or grind ends of specimens that are not plane to within 0.002 in. (0.050 mm).

4. PROCEDURE

- 4.1 Condition the test specimens by submerging in saturated limewater at $73 \pm 4^\circ\text{F}$ ($23 \pm 2^\circ\text{C}$) for at least 48 hours. Conditioning is complete when two successive weighings of the surface-dried sample taken at intervals of 24 hours show an increase in weight of less than 0.5%. Remove surface moisture with a towel.
- 4.2 Place a support frame for each specimen, with LVDT attached, in the water bath.
- 4.3 Remove the specimen from the saturation tank and measure its length at room temperature to the nearest 0.004 in. (0.1 mm). Record this length as L.
Note 1—All measurements must be complete within 5 minutes after removing the specimen from the saturation tank.
- 4.4 Place the specimen in the measuring apparatus located in the controlled temperature bath, making sure that the LVDT tip seats against the upper end of the specimen, and the lower end of the specimen seats firmly against the support buttons, as confirmed by a stable LVDT reading. Be careful not to bang or jar the LVDT tip.
- 4.5 Take readings of the temperature, LVDT (displacement), and the time at 1-minute intervals for the entire duration of the test.
- 4.6 Set the temperature of the water bath to $10 \pm 1^\circ\text{C}$ ($50 \pm 2^\circ\text{F}$). Maintain this temperature for 1 hour.
- 4.7 Set the temperature of the water bath to $50 \pm 1^\circ\text{C}$ ($122 \pm 2^\circ\text{F}$) and allow a minimum of 2 hours, 10 minutes to pass for water to heat to set temperature. Maintain this temperature for 1 hour.

Note 2—Perform tests to verify the length of time needed to achieve the 50°C (72°F) temperature swing for the specific model of water bath used.

- 4.8 Set the temperature of the water bath to $10 \pm 1^\circ\text{C}$ ($50 \pm 2^\circ\text{F}$) and allow a minimum of 2 hours, 10 minutes for water to heat to set temperature. Maintain this temperature for 1 hour.
- 4.9 This completes one test cycle. Refer to Figure 2 for graphical representation of a test cycle.

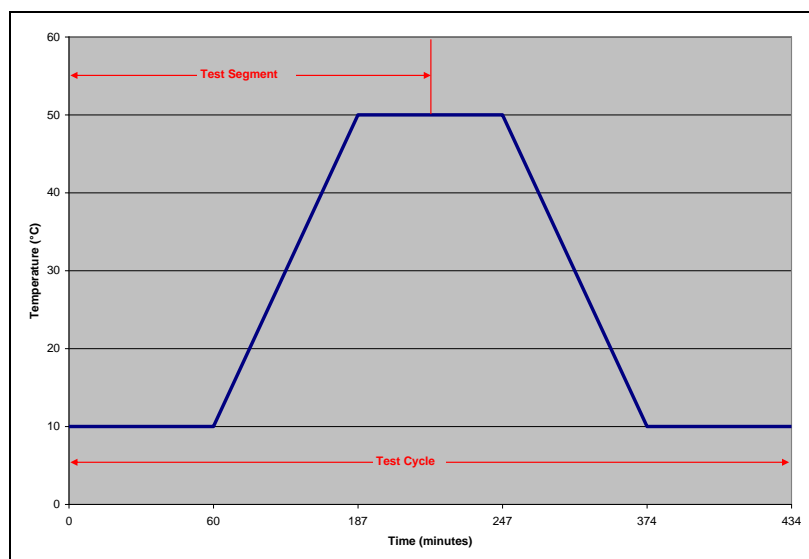


Figure 2—Test Segment and Test Cycle

- 4.10 Repeat Sections 4.6 and 4.7 twice, to total three cycles.

5. CALCULATIONS

- 5.1 For each test specimen, plot temperature vs. displacement. Only use increasing or decreasing temperature points. Do not use temperature-maintaining points. Perform regression analysis. For each specimen, there will be two lines: one for the increasing temperature period and one for the decreasing temperature period. These lines should be parallel to one another. (See Figure 3 for an example using Frame B.) The R^2 value should be greater than 0.9990. Find the slope of each line, M . Use the following equation to compute the CTE value.

English Units:

$$CTE = \frac{M}{L * 1.8} + C_f$$

Metric Units:

$$CTE = \frac{M}{L} + C_f$$

Where:

CTE = coefficient of thermal expansion value

M = slope of line, in./°F (mm/°C)

L = length of specimen, in. (mm)

1.8 = conversion factor required to obtain results in terms of °F

C_f = correction factor for support frame.

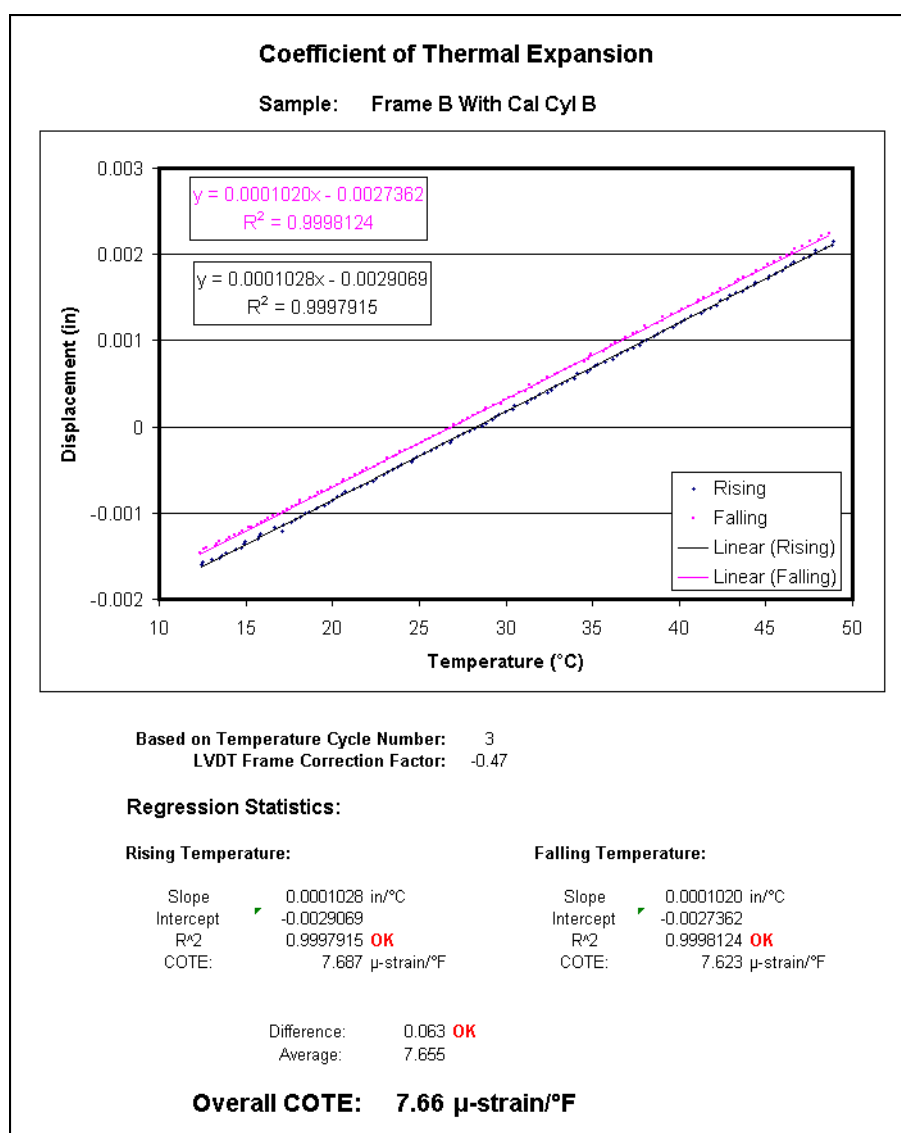


Figure 3—Example Calculations

- 5.1.1 The difference between the CTE value for the decreasing temperature period and the increasing temperature period must be less than or equal to 0.30 micro strains/°F (0.50 micro strains/°C). If the difference exceeds this tolerance, conduct additional test segments until two successive test segments yield CTE values within allowable tolerances. Take the average of the two CTE values. This is the final CTE value for the individual specimen.
- 5.1.2 The difference between specimens must be less than 0.50 micro strains/°F (0.30 micro strains/°C). If this tolerance is exceeded, one or more additional test segments per specimen should be completed until two successive test segments yield CTE values within allowable tolerances. Find the average CTE value of all specimens. This is the final CTE value.

6. REPORT

- 6.1 Include the following in the report:
- Identification number
 - Age of specimens
 - Length of specimen to the nearest 0.001 in. (0.025 mm)
 - Type of aggregate in specimen
 - Individual CTE Value, displayed to three significant digits
- Example: $CTE = 7.66 \times 10^{-6}/^{\circ}F$
- Average CTE Value for all specimens, displayed to two significant digits
- Example: $CTE = 7.7 \times 10^{-6}/^{\circ}F$

PART II—DETERMINING CORRECTION FACTOR

7. PROCEDURE

- 7.1 Conduct Sections 4.2–4.8 using the reference bar as the test specimen. Perform annually.
- Note 3**—Keep the reference bar in a clean, dry location. It will not be placed in the saturation tank.

8. CALCULATIONS

- 8.1 Plot temperature vs. displacement. Only use increasing or decreasing temperature points. Do not use temperature maintaining points. Perform regression analysis. There will be two lines: one for the increasing temperature period and one for the decreasing temperature period. The lines should be parallel to one another. (See Figure 3 for an example.) Find the R^2 value for each line. The R^2 value should be greater than 0.999. Find the slope of each line, M . Use the following equation to compute the CTE value for the reference bar.

English Units:

$$CTE_R = \frac{M}{L * 1.8}$$

Metric Units

$$CTE_R = \frac{M}{L}$$

- 8.2 Calculate the correction factor (C_f) and record to three significant digits:

$$C_f = K - CTE_R$$

Where:

K = known coefficient of thermal expansion of reference bar.

PART III—CALIBRATION OF LVDT AND RTD

9. PROCEDURE

- 9.1 Perform LVDT calibration quarterly in accordance with the manufacturer's instructions.
- 9.2 Perform RTD calibration semi-annually in accordance with Tex-926-K.

PART IV—COARSE AGGREGATE PIT TESTING

10. STANDARD MIX DESIGN

- 10.1 Materials—The following quantities will yield 0.75 cu. ft. of concrete. Adjustments may be made based on limitations of concrete mixer used.
- 10.1.1 Fine Aggregate—Use 51.44 pounds of fine aggregate from Capitol Aggregates, Bolm Road pit or equivalent.
- 10.1.2 Coarse Aggregate—Sieve the coarse aggregate and recombine in accordance with the requirements in Table 1.

Table 1—Standard Gradation

Sieve Size		Mass (pounds)
Passing	Retained	
1 "	3/4"	18.7
3/4"	1/2"	39.2
1/2"	#4	27.3

- 10.1.3 Cement—Use 23.45 pounds of cement meeting the requirements for Type I/II Portland cement as specified in ASTM C 150.
- 10.1.4 Water—Use 11.49 pounds of water meeting the requirements of a municipal water source.

11. SPECIMEN PREPARATION

- 11.1 Using the standard mix design, mix concrete in accordance with the standard practice for making and curing concrete test specimens in the laboratory in accordance with ASTM C 192.
- 11.2 Prepare a minimum of four 4 × 8 in. cylinders and cure in accordance with ASTM C 192.
- 11.3 Test a minimum of two of the prepared cylinders at 28 days in accordance with Tex-428-A, Part I.

12. ARCHIVED VERSIONS

- 12.1 Archived versions are available.